Appendix C: Studies of Noise Impact of Oil Industry Activities on the Bowhead Whale Migration and on the Subsistence Whaling Activities

1. LGL Ecological Research Associates, Inc. *Behavior, Disturbances, Responses and Feeding of Bowhead Whales in the Beaufort Sea, 1980*. Prepared for the Bureau of Land Management (BLM). April 1981.

   Summary: Bowheads responded to boats in two ways. At 2.3 miles (3.7 km) from a 52 ft. (16 m) boat, bowheads decreased time at surface and number of blows per surfacing and increased the variability of these characteristics. When boats of 52 ft. and 197 ft. (16 m and 60 m) closed to within 0.62 mile (1 km), whales swam away from the boat and scattered, but did not leave the locale. Bowheads typically dove in response to aircraft at 1,000 ft. level (305 m), but not at 1,500 ft. level (457 m). Bowheads were frequently seen 3 miles (5 km) from an artificial island under construction, some as close as 2,625 ft. (800 m), and one bowhead came to 60 ft. (16 m) from a barge (p. 94). Some of the whales appeared to tolerate both the physical presence of the artificial island, boats, dredge, and the operating sounds produced (p. 149). Bowheads at 8 miles (13 km) from an active seismic vessel did not behave in any obviously disturbed manner (p. 185).

2. North Slope Borough (NSB). *Review of MMS, USDOI, Plan to Monitor the Interaction Between Fall Migrating Bowhead Whales and Geophysical Vessels in the Alaskan Beaufort Sea.* August 1982.

   Summary: Behavioral parameters have not been adequately qualified. It is not presented clearly as to how bowhead whale behavior will be judged to be abnormal. Until normal behavior has been reasonably well documented, abnormal behavior cannot be fairly and adequately judged. The concept of the zone of influence has been neither defined nor discussed in any of the documents. This understanding of the concept of zone of influence could potentially lead to significant differences of opinion (p. 6). There are too many unknowns, unqualified statements and oversights in the task statements and methods to say that the bowhead will be adequately protected when seismic exploration activities are conducted (p. 7).

3. Gales, R. S. Bureau of Land Management. *Effects of Noise of Offshore Oil and Gas Operations on Marine Mammals.* Naval Ocean Systems Center (NOSC), Technical Report 844, Vols. I and II. September 1982.

   Summary: Oil and gas platforms produce significant underwater noise with the highest level component below 100 hz (hertz). The platforms produce less noise than the propellers of supply boats. Platforms can be designed for reduced sound emission. Platform noises may be detected by mysticete whales at great distances, but the more likely range in the Lower Cook Inlet is 10,500 ft. (2 mi.) Whales either ignore or avoid the platforms without appreciable change in behavior in the Cook Inlet area where they have a long history of exposure to noise of ships. This may or may not be true of the Beaufort Sea, which is not covered by this study (p. 2).

4. LGL Ecological Research Associates, Inc. *Behavior, Disturbance Responses and Feeding of Bowhead Whales Balaena mysticetus in the Beaufort Sea, 1980-81*. Prepared for BLM. August 1982.

   Summary: Bowheads reacted to boats or small ships in two main ways: 1) When boats were nearby, bowheads altered their surfacing and diving patterns by decreasing the mean time at the surface and mean dive duration. This was done even with a stationary 52 ft. (16 m) boat with engines idling at range of 1.8-

2.5 mi. (3-4 km). 2) When boats closed to 1-1.8 mi. (1-3 km), the whales, in addition to above responses, swam rapidly away from the boat and scattered. Whales directly in the boat's track initially tried to outrun it, but usually turned off as the boat closed to within a few hundred meters. None of the whales left the area, however. In response to aircraft, at 1,000 ft. altitude (305 m), the whales dove. They dove only occasionally in response to aircraft at 1,500 ft. altitude (457 m). Bowheads were sighted as close as 3.5-7.7 mi. (6-13 km) from a seismic ship firing 12 large sleeve exploders. Surfacing and respiration behavior was similar to that without seismic noise. Sightings of bowheads were reported at 1.2-4.3 mi. (2-7 km) from a seismic ship that uses airguns. Sonobuoys showed that bowheads often continued to call in the presence of seismic noise. There was circumstantial evidence of habituation to seismic noise. Bowheads were frequently seen 3 mi. (5 km) from an artificial island that was under construction by a dredge. Bowheads were sighted as close as 2,624 ft. (800 m) and one as close as 52 ft. (16 m). Sounds from the dredge were well above ambient levels. Bowheads were sighted as close as 2.5 mi. (4 km) from a drillship, and industry has reported closer sightings. Behavior was different from that in the absence of the drillship, but also different from behavior with boat or airgun disturbance (p. 23-24).

5. LGL Ecological Research Associates, Inc. *Behavior, Disturbance Responses and Distribution of Bowhead Whales Balaena mysticetus in the Eastern Beaufort Sea, 1982*. Prepared for MMS. November 1983.

   This report is much the same as previous 1982 report, with some additional information. In the presence of stronger seismic noise, whales began to swim rapidly away at 1.2-1.8 mi. (2-3 km). It was concluded that bowheads react strongly to an approaching boat even when they have already been exposed to intense sounds from seismic exploration before the boat approaches (p. 13). None of the boat disturbances resulted in long-distance displacement. Reaction to circling aircraft was conspicuous at 1,000 ft. (305 m), occasional but not major at 1,500 ft. (457 m), and undetectable at 2,000 ft. (610 m) (p. 14). In the presence of seismic noise, behavior patterns of bowheads were not consistently altered. This seems to indicate habituation to ongoing seismic noise. The results show that bowheads do not swim away from seismic vessels operating 3.5 mi. (6 km) or more away (p. 15-16). Also, there was no consistent indication of unusual behavior among whales observed within 12.5 mi. (20 km) of drillships (p. 16). Overall, the results show that the behavior of bowheads can be affected markedly by the close approach of ships or aircraft. However, the whales seem to return to their normal activities soon after the ship or plane moves away. Seismic exploration occurred over much of the Canadian Beaufort Sea, both within and beyond the "main industrial area," the region off the McKenzie Delta where there is island construction, drilling, dredging, and intensive support traffic via boat and helicopter. Regardless of whether or not industrial activities affect bowhead distribution in summer, bowhead movements probably depend more on the distribution and abundance of zooplankton. Factors affecting zooplankton in the eastern Beaufort Sea are poorly known, but probably include the variable volume and movement of fresh water from the McKenzie River, and hydrodynamic phenomena at the shelf break and the ice edge. The variable distribution of ice probably also has direct effect on whale distribution (p. 21-22).

6. American Petroleum Institute. *Effects of Offshore Petroleum Operations on Cold Water Marine Mammals.* Report No. 4370. October 1983.

   Summary: Toothed and baleen whales sometimes dive or turn away from aircraft noise, but sensitivity seems to vary depending on the activity of the animals and the effects are transient. Limited evidence seems to indicate that seals normally show considerable tolerance of noise and other stimuli from ships and boats. Toothed whales show some tolerance, but may react at distances of several kilometers, when confined by ice or shallow water, or when they have learned to associate the vessel with harassment. Gray and bowhead whales have often been observed behaving normally and will continue calling in the presence of strong seismic sounds. Short-term behavioral reactions and temporary displacement of whales and hauled-out pinnipeds may take place from certain offshore operations of the oil industry such as ship traffic and aircraft overflights. Overflights of hauled-out areas may cause mortality through stampedes or abandonment. However, the continued presence of various marine mammals in certain areas despite intense ship traffic, fishing, hunting, sealing, etc. for many decades suggests many mammals are tolerant of much human activity (p.xvii-xviii).

7. LGL Ecological Research Associates, Inc. *Behavior, Disturbance Responses and Distribution of Bowhead*

Whales Balaena mysticetus in the Eastern Beaufort Sea, 1980-84. Prepared for OCS Study, MMS 85-0034. June 1985.

Summary*:* Bowhead behavior was markedly but temporarily affected by the close approach of ships or aircraft. Bowheads sometimes came within 3.1 mi. (5 km) of drillships and dredges without avoidance. Seismic noise caused some subtle alterations of surfacing, respiration (blows), and diving behavior at 3.5 mi. (6 km) (p. 92). Except in shallow water, behavior can almost always be considered "presumably unaffected by aircraft" if the aircraft remains at 1,500 ft. (457 m). Reduced blow time occurred during prolonged circling at low altitude of aircraft, however, during actual offshore operations whales would be exposed to single passes, rarely to circling aircraft (p. 106-7).

8. Llungblad, D. K., B. Wursig, S. L. Swartz, and J. M. Keene. *Observations on the Behavior of Bowhead Whales in the Presence of Operating Seismic Exploration Vessels in the Alaskan Beaufort Sea.* Prepared for OCS Study, MMS 85-0076. Prepared by SEACO, Inc. October 1985.

   Summary: Whales responded to seismic sounds at ranges of less than 6.2 mi. (10 km), with the strongest responses occurring at 3.1 mi. (5 km). Responses consisted of blow interval increase, number of blows per surfacing, length of surfacing, and length of dive all decreasing with the onset of seismic sounds. Whales recovered to pre-seismic conditions within 30 to 60 minutes of the termination of the seismic sounds (p. 45). It is possible that bowheads directly abeam of an active geophysical vessel could be exposed to greater levels of seismic sounds than if they were directly in front or behind the vessel at the same distance, and that the behavior changes observed at ranges less than 3.1 mi. (5 km) might occur at ranges greater than this at either side of an active geophysical vessel (p. 47).

9. Llungblad, D. K., NOSC, and S. E. Moore, J. T. Clarke, and J. C. Bennett, SEACO, Inc. *Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and the Alaskan Beaufort Sea, 1985, With a Seven Year Review, 1979-85*. Prepared for MMS, Alaska OCS Region, MMS 86-0002, TR-1111. August 1986.

   Summary: Five OCS drill sites were active at various times during fall 1985 with activity including drilling, casing, cementing, logging, testing, as well as daily helicopter and vessel (tugboats and icebreakers) support efforts. These sites include the concrete island drilling structure (CIDS) anchored at Orion Prospect near Point Lonely, the drillship *Canmar Explorer II* at Hammerhead Prospect, Sandpiper Island, and Corona Prospect to which the *Canmar Explorer II* was moved after work was completed at Hammerhead. Bowhead whales were sighted from 9.4 mi. (16 km) to 122 mi. (197 km) from these activities. It does not appear that industrial noise affected whale movements because bowhead distribution near these sites was not appreciably different from that of prior years (p. 49- 53). The results of surveys from 1979-85 have been finalized in NOSC technical documents or technical reports (Ljungblad 1981; Ljungblad et al, 1980-85, and in summary manuscripts presented at the International Whaling Commission annual meetings (p. 63).

10. LGL Limited and Greeneridge Sciences Inc. *Bowhead Whales and Underwater Noise Near the Sandpiper Island Drillsite, Alaskan Beaufort Sea, Autumn 1985*. Prepared for Shell Western Exploration and Production, Inc. 1986.

    Summary: Most of the noise from this artificial island came from the power generator as actual drilling ceased during whale migration and did not resume until the migration was nearly over. Intensive aerial surveys were made to determine the distribution and movement patterns of the bowhead whales within 46.6 miles (75 km) of Sandpiper Island. No bowheads were seen closer than 17.7 miles (30 km) and nearly all were in waters deeper than 59 feet (18 m), which is considerably farther offshore than the island. The low number of sightings and the concentration of the whales in the 18-50 m depth zone were consistent with results from other simultaneous studies elsewhere in the Alaskan Beaufort Sea in 1985 (p. ii).

11. McLaren, P. L., C. R. Greene, W. J. Richardson, and R. A. Davis. LGL Limited Environmental Research Associates and Greeneridge Sciences, Inc. *Bowhead Whales and Underwater Noise Near a Drillship*

Operation in the Alaskan Beaufort Sea, 1985. Prepared for Unocal Corporation, Oil and Gas Division. December 1986.

The Canmar Explorer II and support vessels, including supply ships and icebreaker were used at the Hammerhead prospect north of Flaxman Island in the Alaskan Beaufort Sea. Bowheads were first sighted on Sept. 1 and last sighted on Oct. 15. A significant portion of the industrial noise produced was from the support vessels, rather than the drillship itself. Also, received levels at a given range from the drillship were greater in the port and starboard beam aspects than in the bow aspect. Migration appears to have been later than previous years. In 1982 bowhead were not seen after Oct. 6 east of 150° and in 1984 the last sighting was on Oct. 5. Bowheads also appeared to be concentrated at the 59-174 ft. (18-50 m) depth range. Only one of the 68 whales seen from 144-150° was outside this range. This was similar to previous years. Apparent numbers and densities of whales through the Hammerhead study area were low relative to other years. No whales were seen closer than 15 mi. (26 km) at any time during the autumn migration. In contrast, larger numbers of bowheads were seen in previous years at the 59-98 ft. (18-30 m) depth. The scarcity of bowheads near Hammerhead did not appear to have any connection to the drilling operation. Results from other studies east and west of Hammerhead were similar. Densities of bowheads were low and few whales were seen inside the 98 ft. (30 m) depth. Actual drilling at Hammerhead ended before the bowheads began migrating through the area, and most passed Hammerhead after the drillship had left the drillsite. Thus, the general scarcity of whales and the lack of sightings inshore of the 59 ft. (30 m) contour cannot be attributed to industrial activities at Hammerhead (p. xxi-iv).

12. LGL Ecological Research Associates, Inc. *Importance of the Eastern Alaska Beaufort Sea to Feeding Bowhead Whales, 1985-86.* OCS Study, MMS 87-0037. August 1987.

    Summary: The 42 ft. (12 m) boat used in the study caused the whales feeding off the Kongakut Delta to swim rapidly offshore from the feeding area, into deeper water several kilometers away. The next day several whales were sighted feeding again, including three identified from the previous day (p. 475). Noise pulses of faint to moderate intensity from seismic activities 6.2-12.4 mi. (10 to 20 km) away did not cause the whales to cease feeding (p. 475). Some bowheads fed in areas of drillship and dredge activity, but a moving support vessel within 1-2.5 mi. (1-4 km) is known to disturb the whales (p. 476). A single nearshore industrial site might displace bowheads from all parts of a small nearshore feeding area, but probably not from an elongated one. Multiple activities distributed along a significant length of coast might deny bowheads the use of an entire nearshore feeding area. Certain nearshore areas seem to be recurring feeding areas, while offshore feeding locations are apparently not at fixed positions and no one site is likely to remain a potential feeding area for long (p. 478).

13. Ljungblad, D. K., S. E. Moore, J. T. Clarke, and J. C. Bennett. *Distribution, Abundance, Behavior, and Bioacoustics of Endangered Whales in the Alaskan Beaufort and Eastern Chukchi Seas, 1979-86.* Naval Ocean Systems Management Service, Alaskan Region. MMS, OCS Study, MMS 87-0039. 1987.

    Summary: Bowheads that appear to feed in the Alaskan Beaufort Sea in August are generally farther offshore and in deeper water than those seen in September and October. There may be considerable movement of whales back and forth between the Canadian and Alaskan Beaufort Seas prior to the onset of migration. The fall migration began between Sept. 2-7 in all years except 1979 (Aug. 20), and 1985 (Sept. 22), and lasted an average of 43 days. Bowhead daily sighting rates were relatively low and few whales were seen feeding in the Alaskan Beaufort Sea west of Barter Island in 1986, a year of light ice-cover. The 1986 season was unique with respect to the distance the ice edge was offshore during September and early October, and may somehow account for the sparsity of nearshore feeding. Although there is some annual variability, it appears that except for 1983, the bowhead whale migration route may be roughly demarcated by the 20 to 40 meter isobath (65-131 ft.), and that the effects of OCS oil and gas development activities on the axis of the migration (as defined by median depth) are slight. Feeding whales are seen in shallower water and in lighter ice-cover than whales not feeding. Bowheads seem to be strongly associated with the ice edge as they overwinter in the Bering Sea (Ljungblad et al., 1986). A similar association may be true during fall migrations when a defined ice edge exists far offshore over water deep enough to permit ice-induced upwelling (p. 173-5).

14. Davis, Rolf A. LGL Limited and Greeneridge Sciences, Inc. *Responses of Bowhead Whales to an Offshore Drilling Operation in the Alaskan Beaufort Sea, Autumn 1986.* Prepared for Shell Western E & P Inc. November 1987.

    Summary: The general results of this behavior study showed that during migration (Sept. 19-Oct. 9), the surfacing, respiration, and diving variables tended to increase with increasing distance from active ships. However, the correlations were weak, suggesting that other variables such as whale activity, seismic activity, sea state, ice cover, water depth and date also may affect the behavior of migrating bowheads. It is also likely that even at the same distance some whales react more strongly than others (p. 118). A mother and calf were observed for several hours. The mother initially was water column feeding and the calf was seen playing with a log after a seismic vessel had approached to about 10.5 mi. (17 km) from the whales (p. 70). A single large whale was observed feeding even though the Robert Lemeur (Class III icebreaker) approached to 8 mi. (13 km) and the drillship was about 13.6 mi. (22 km) away (p. 74). Another whale turned and moved around the drillship along an arc 14.2-16.7 mi. (23-27 km) from the drillship. The whale exhibited evidence of disturbance as it first turned northward, but its behavior stabilized after 1.5-2.0 hours (p. 116). Two large adult bowhead whales were sighted migrating at 14.2 mi. (23 km) from the drillship. After the first four surfacings the whales showed no evidence of being disturbed. The surfacing-dive patterns and respiration variables differed between the two whales, illustrating that substantial variation can occur among these variables for similar-sized whales in the same circumstances (p. 83).

15. Review Conducted by NSB Science Advisory Committee, requested by George N. Ahmaogak, Sr., Mayor, NSB. *A Review of the Report "Importance of the Eastern Alaskan Beaufort to Feeding Bowhead Whales, 1985-86"* MMS, OCS Study, MMS 87-0037. December 1987.

    Summary: What emerges from this research program is a compilation of related studies which in themselves contribute to a growing understanding of the environment of the Eastern Alaskan Beaufort Sea, but do not constitute an irrefutable evaluation of the importance of the region to the stock as a whole or to selected members of the population. The review committee does not accept the conclusion made by the investigators that the study area is unimportant as a feeding area for bowhead whales.

16. USDOI, MMS, Alaska OCS Region, OCS Study, MMS 88-0030, *Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1987.* 1988.

    Summary: The closest sighting of a bowhead whale was at a distance of 9.3 km from a nonoperational drilling structure (SSDC-single steel drilling caisson), and its behavior appeared normal, i. e., it was swimming at a moderate speed. Four other sightings of six bowhead whales were made, but their response was not noted (p. 73).

17. Ljungblad, Donald K., Bernd Wursig, Steven L. Swartz, and James M. Keene. *Observations on the Behavioral Responses of Bowhead Whales (Balaena mysticetus) to Active Geophysical Vessels in the Alaskan Beaufort Sea*. In Arctic, Vol. 41, No. 3 (September 1988), P. 183-194.

    Summary: Whales responded to airgun blasts at ranges of less than 6.2 miles (10 km), with the strongest responses occurring within the 3.1 mile (5 km) range. Site-specific behavior (i. e., traveling vs. milling/feeding) may influence the whales' responses to approaching seismic vessels. Also, the tendency of the whales to dive for shorter periods of time during seismic activity may be related to the fact that sounds are reduced near the surface of the water. Swimming near the surface may help avoid higher levels of sound in deeper water. The whales recovered to normal behavior within 30-60 minutes from cessation of airgun activities.

18. LGL Limited Environmental Research Associates. *Comparison of Behavior of Bowhead Whales of the Davis Strait and Bering/Beaufort Stocks.* Prepared for MMS, OCS Study, MMS 88-0056. March 1989.

    Summary: The conclusion is that, for migrating bowheads, at least two specific aspects of behavior--dive duration and frequency of fluke-out dives--appear to differ significantly between the eastern and western

arctic. One can speculate, that the longer dive durations of migrating whales in the western arctic would make them less accessible to hunters. Consequently, this difference in behavior might be related to the continuing bowhead hunt. Likewise, the lower frequency of fluke-out dives by migrants might be related to the fact that this behavior increases the conspicuousness of a whale to hunters (p. 114).

19. LGL Ecological Research Associates. *Synthesis of Information on the Effects of Noise Disturbance on Major Haulout Concentrations of Bering Sea Pinnipeds*. Prepared for MMS, OCS Study, MMS 88-0092. 1988.

    Summary: Studies found that hauled-out pinnipeds reacted most strongly when approached by aircraft at low altitudes, sometimes stampeding into the water with some mortality. They also became alert and agitated to the point of temporarily leaving their haulout sites when boats approached closer than 196 feet (60 m). Repeated disturbance has caused abandonment of some haulout areas.

20. Richardson, W. J., C. R. Greene, Jr., W. R. Koski, C. I. Malme, G. W. Miller, M. A. Smutea, and B. Wursig, for LGL Limited Environmental Research Associates. *Acoustic Effects of Oil Production Activities on Bowhead and White Whales During Spring Migration Near Pt. Barrow, Alaska, 1989 Phase: Sound propagation and whale responses to playbacks of continuous drilling noise from an ice platform as studied in pack ice conditions.* For MMS, OCS Study, MMS 90-0017. July 1990.

    Summary: Previous studies show that bowhead sensitivity to manmade noise varies. It is possible that there is additional variation in sensitivity in spring because some bowheads, before reaching the study area, are pursued by whaling crews. Thus, it would not be surprising if some individual whales migrated past the project at relatively close distances while other bowheads showed avoidance reactions even to weak industrial sounds (xvi). No studies have been made on the disturbance reactions of bowheads migrating in the spring leads. The sounds considered in the summer-autumn studies in the Beaufort Sea have been those associated with offshore exploration activities, ie: aircraft, boats, seismic exploration, drillships, and offshore construction (p. 1). Only limited data have been acquired to date on reactions of bowheads to noise playbacks in spring lead systems. Some bowheads migrating through the pack ice east of Point Barrow in the spring tolerated low-frequency drilling noise without interrupting or diverting their migration. Other individuals may have reacted strongly to the same level of drilling noise (p. 247). However, it should not be assumed that all bowheads migrating in spring would tolerate the same levels of sound at the same distances or behave the same way to other types of industrial sound (p. 247).

21. ARCO Alaska, Inc. *1990 Bowhead Whaling Season, Beaufort Sea, Alaska*. The 1990 Beaufort Sea whale migration. Where were bowhead whales observed, when, and by whom during the period of the subsistence hunt by Kaktovik, Nuiqsut, and Barrow whalers. 1990.

    Summary: Both seismic operations and whaling were precluded from normal operations by high winds and heavy seas during much of the study period. Drilling platform activities were the Stinson program (CIDS) west Camden Bay and the Fireweed program (SSDC/MAT) 13 miles offshore from Pitt Point. These were winter drilling operations from bottom-founded units. Towing the drilling platforms to and from their operating locations and a single tug barge supply trip were the only open-water activities. Helicopter flights were kept to the crew shift changes, inspections by regulatory officials, and operational needs. An altitude of 1,500 ft. (457 m) was maintained over possible whale migratory routes and active whaling areas were avoided. No drilling took place during the fall subsistence whale hunt. Seismic activities were coordinated to avoid conflicts with the whaling crews. Given the known swimming speeds of migrating bowheads and matching those speeds to actual sighting locations, the conclusion can be drawn that groups of whales were widely distributed across the Alaskan Beaufort Sea all the way from Barter Island to Barrow from mid-September through mid-October. This brings into question the hypothesis that the whales are “bottled up” as a result of seismic activities. In fact, active seismic operations were being conducted at both the west Camden Bay and southeast Harrison Bay locations during the periods when whaling crews were striking whales at Kaktovik, Cross Island, and Barrow. Whales were present and observed on all dates at all three hunting locations as well as in the general vicinity of the seismic operations. Seismic influence, if any, did not block the migration at any observed location. Numerous bowhead whale groups were observed migrating within a visually observable distance

of active seismic operations on many occasions. This leads to the conclusion that seismic sound production does not significantly influence observed migrations of baleen whales. This view is not fully shared by Inupiat whales who point to their own historical observations that in some years bowheads have not been sighted in expected use areas when seismic activity has been conducted. Serious weight was given to Inupiat historical observations in scheduling the 1990 seismic activities and those activities were carried out in consultation with experienced whalers so that any potential effects on known hunting areas and whaling activities could be reduced to the minimum.

22. Hall, J. D. and J. Francine, Hubbs Marine Research Center. Technical Report 89-219. *Report on Sound Monitoring and Bowhead Whale Calls Localization Efforts Associated with the Concrete Island Drilling Structure (CIDS) off Camden Bay, Alaska.* Prepared for ARCO Alaska Incorporated. February 1990.

    Summary: The sound produced by the CIDS, and presumably other drilling rigs using rotary turntables, is below 10 Hz. Baleen whales may well perceive some of the low frequencies produced by drilling rigs. They may be able to perceive 5 Hz sounds at more than 1,968 ft. (600 m). Bowhead whales were observed as close as 0.62 mi.. to .92 mi. (1-1.5 km) from the CIDS which was operating at "idle," and one whale was observed at 656 ft. (200 m) from the CIDS. Sounds of high-speed outboard propellers approaching were heard which were the outboard motors on Native whaling vessels. The Native whalers had sighted the whales near the CIDS and were able to successfully strike at least one whale (p. 16).

23. Hall, J. D., M. L. Gallagher, and K. D. Brewer, Coastal & Offshore Pacific Corporation and D. K. Ljungblad, Ljungblad Associates. *Passive Acoustic Monitoring Program at the ARCO Alaska, Inc. "Fireweed" Prospect, Sep-Oct, 1990.* April 1991.

    Summary: The acoustic monitoring period was conducted between Sept. 16 - Oct. 11, 1990 on a 24 hour/day basis. A total of 254 bowhead whale calls were heard or recorded. The peak calling period was on Oct. 1st and 2nd, with 93% of all calls recorded on those days. Over 77% of these calls were heard during hours of darkness, a pattern that is consistent with other studies. The closest point of approach to the SSDC (operating at idle) was 3.2 mi. (5.2 km) for a calling bowhead whale. The closest point physically was 328 ft. (100 m) when 18 whales were sighted from the platform. A whale was heard to rub against one of the sonobuoys (p. 3). A group of 13 bowhead whales changed their swim course and approached to within 820 ft. (250 m) of the CIDS, also operating at idle (p. 35)

24. USDOI, MMS, Alaska OCS Region, OCS Study, MMS 91-0055. *Aerial Surveys of Endangered Whales in the Beaufort Sea, Fall 1990.* 1991.

    Summary: The mean water depth of bowhead whales at random sightings during 1990 was 128 ft. (38.8 m), less than the mean for each of the previous years, except for 1989 74 ft. (22.7). The reasons for the deep-water migratory route of 1983, 1,138 ft. (347 m), and the comparatively shallower route of 1990 and other years may be attributable to general ice cover. Differences in human activity levels, oceanographic conditions, and the possible indirect effect of heavy ice cover on prey availability are additional potential factors. Ice cover probably has the greatest potential for interacting with environmental conditions that, in turn, may have biological significance to migrating bowhead whale (net primary production, availability of leads, water temperature). During 1983, the most severe ice year since 1975, the bowhead migration was observed in water deeper than for other years. The mildest ice year since 1979 was 1990 and bowhead migration was observed at an average median and a comparatively shallower mean depth (p. 53). To prevent potential effects on subsistence whaling, seismic operations ceased when whales were visible from the exploration vessel, until the whale migration passed through the area of operations. Bowhead whales were observed in the vicinity of the SSDC situated north of Cape Halkett at the Fireweed drilling site. The closest distance of the bowhead was at 2.2 mi. (3.6 km) from the nonoperational drilling structure (p. 60).

25. Miller, G. W., R. A. Davis, and W. J Richardson,.LGL Limited Environmental Research Associates. *Behavior of Bowhead Whales of the Davis Strait and Bering/Beaufort Stocks vs. Regional Differences in Human Activities.* Prepared for OCS Study, MMS 91-0029. 1991.

Summary: Human activity studies in the eastern and western arctic made for the period of 1974-1986 include oil industry activity. The most intense, and potentially most disturbing, human activities are subsistence whaling, commercial vessel traffic, and marine seismic activities. Bowheads of the Bering/Beaufort stock have been subjected to at least 3 to 5 times as much disturbance as have the bowheads of the Davis Strait stock. It was concluded that most of the differences in behavior between the two stocks were better explained by environmental or biological factors rather than by disturbance. In the case of bowheads migrating in the autumn, there were statistically significant differences in behavior that tended to make bowheads of the Bering/Beaufort stock less conspicuous. This may have been a response to subsistence whaling in the Beaufort Sea (p iv). These bowheads spend less time at the surface and exhibit fewer fluke-out dives. It is even more uncommon for bowheads migrating near Pt. Barrow in spring to fluke-out upon diving. It is possible that the bowheads have adopted these behaviors at least partly in response to the increased industrial disturbance in the Beaufort Sea. However, it seems more likely that these actions are the whales' survival tactics to make themselves less detectable in response to the fairly intensive subsistence whaling that has occurred along the migration routes of the Bering/Beaufort stock for many decades (p. 93).

26. Richardson, W. J., C. R. Greene Jr., W. R. Koski, and M. A. Smultea, assisted by G. Cameron, C. Holdsworth, G. Miller, T. Woodley, and B. Wursig. LGL Limited Environmental Research Associates. *Acoustic Effects of Oil Production Activities on Bowhead and White Whales Visible During Spring Migration Near Pt. Barrow, Alaska--1990 Phase*. Prepared for MMS, OCS Study, MMS 91-0037. October 1991.

    Summary: Migrating bowheads will tolerate high levels of continuous drilling noise in order to continue their migration. The bowheads migrated along a long, narrow lead, 656 feet (200 m) wide, through otherwise heavy pack ice. However, as the whales approached the source of the drilling sounds, they crossed to the far side when about 1,310 feet (400 m) away. In other less tight leads, there was no evidence the bowheads migration was blocked by the drilling sounds, and no evidence that bowheads avoided the source by distances exceeding 0.62 mile (1 km). Usually, the divergence from the migratory path did not take place until the whales were within a few hundred meters of the source (p. xvi-iii).

27. Coastal and Offshore Pacific Corporation. 1993 Kuvlum Exploration Prospect Site Specific *Monitoring Program Final Report.* Prepared for ARCO Alaska, Inc., May 20, 1994.

    Summary: This study compiled the results of a three-year monitoring program conducted in the Camden Bay region between 1991 and 1993. The purpose of the study was to document the responses of marine mammals to the presence of an active floating conical drilling unit, and associated ice management (ice breaker), supply, support and seismic vessels. The distribution, behavior and abundance of bowhead whales near exploration activities was estimated with aerial surveys, and the use of sonar buoys and hydrophones during summer and fall of 1993. Researchers investigated bowhead whale distribution and proximity to shore with factors such as water depth, longitude, and noise levels. Distance of whales offshore was statistically correlated with these factors, but variability was high, and thus, predictability of whale distribution was poor. Water depth was the only factor that explained a significant portion of the variability in the distribution of whales offshore. The study concluded that this distribution varies greatly between individual years and that "the factors most likely to influence their behavior and distribution are ice cover, bathymetry and food resource availability." (COPAC, 1994:204). The study did report that bowhead whales were distributed significantly closer to shore in areas away from exploration activities. Finally, the report stated that while bowhead sightings did not vary with the presence of ice cover, other marine mammal sightings (walrus, seal, and polar bear) were closely related to the presence of ice.

28. Hurst, R.J., N. A. Øritsland., P.D. Watts, 1982. *Metabolic and temperature responses of polar bears to curde oil.* In: Land water issues in resource development, edited by P. J. Rand. Ann Arbor science Press, MI. pp. 263-280.

    Summary: The metabolic and temperature responses of three sub-adult polar bears were monitored before and after exposure to a one cm. slick of crude oil. Oil adhered to the polar bear fur on contact, suggesting that physical fouling of fur would occur rapidly. The increase in resting metabolic rate of the oiled polar

bears was consistent and substantial. The results also show an increase in body and skin temperatures. The metabolic changes following oil contamination may be due to 1) normal metabolic compensation for a reduction in fur insulation; 2) a direct effect on the minimum level of energy turnover of the tissues; 3) skin reaction in combination of all three mechanisms. The results of this study suggest that following oil exposure the thermo-regulatory balance of a free ranging polar bear would be stressed. This cold lead to serious alterations in activity patterns, hunting strategies, and ultimately survival.

29. Dickson, D.L., J.E. Hines and M.F. Kay. 1997. *Distribution and abundance of Kind Eiders in the Western Canadian Arctic. Irr*. D.L. Dickson (ed.). Occasional Paper No. 94. Canadian Wildlife Service, Ottawa.

    Summary: Population estimates suggest that the Western Arctic population of King Eiders has declined in number. The more recent count of eiders at Point Barrow also indicated a decline; an estimated 30 percent fewer eiders flew past Point Barrow during the spring migration of 1987 then in 1976. King Eiders periodically experience mass mortality during spring migration. In years when leads of open water failed to form in the Beaufort Sea, large numbers of starving and dead King Eiders are found. The low population estimates might be due in part to the most recent die-off, which occurred in 1990. There are, however, several other possible reasons. Given the limited coverage of the breeding ground and unsystematic survey method, estimates could be quite inaccurate. Systematic aerial surveys have been conducted only in about half of the breeding range. A more accurate visibility correction factor with tighter confidence limits should be developed. A study of the changing composition of the King Eider population as the nesting season progresses is needed to determine the degree to which early departure of males is affecting the population estimates. A study is also needed to clarify the eastern and northern limits of the breeding range of the King eiders that winter west of the continent.

30. Neff, J.M., Owens, S.W., Stoker, and D.M. McCormick, *Shoreline oiling conditions in Prince Williams Sound following the Exxon Valdez oil spill.* Pp. 312-346. In: P.G. Wells, N.J. Butler, and J.S. Hughes (eds.). *Exxon Valdez oil spill: fate and effects in Alaskan waters.* Special treatment Publications 1219, American Society for Testing and Materials, Philadelphia.

    Summary: In the three years since the Exxon Valdez oil spill, the amount of surface and subsurface oil on the shoreline of Prince William Sound has decreased dramatically, by nearly 75 percent each year between 1989 in 1992. By the spring of 1992, only about 0.2 percent of the shoreline of Prince William Sound still had any surface oil. A large amount of oil was removed form the shore by a massive cleanup effort mounted during the summer of 1989. Many shores were treated several times by different cleanup methods during the summers of 1989, 1990, and in a few cases, 1991 and 1992. Additional oil was removed from oiled shores by natural weathering processes such as evaporation, dissolution, photooxidation, biodegeneration, and wave action. The results of a 1993 survey demonstrated a continuing decline of residual surface oiling, with only scattered in weathered remnants remaining at some locations. In evaluating cleanup effectiveness, the surface and subsurface oiling data from Prince William Sound indicate that it is prudent to remove oil in the early stages following a spill, before weathering occurs. Reduction rates of surface and subsurface oil were accelerated where 1989 treatment was conducted early (May and June) or where intensive and repeated cleanup was used. Reduction rates were slower in areas treated later that summer and less intensely.

31. Arctic Monitoring and Assessment program (AMAP). 1997. Arctice pollution issues: a state of the Arctic Environmental Report. pp. 153-155. Oslo, Norway.

    The Arctic environment is a more vulnerable to spills than warmer environment because oil breaks down more slowly under cold, dark conditions and because Arctic plants and animals need a longer time to recover from damage. In addition, remedial measures are difficult due to the extreme condition of cold, ice cover, and winter darkness. Oil spills will affect most exposed animals, but the impact will vary greatly depending on the species and circumstance. Although zooplankton can take up components of the oil, the toxic effect appeared to be short lived. Fish eggs and larvae are vulnerable. They often develop near the surface, where they are most likely to be exposed to dissolved oil components. They are also more sensitive to oil toxicity that adult fish. Adult fish in the Arctic are probably no more sensitive to oil spills than fish in other areas, and the experience so far has been that even large oil spills have had no

apparent impact. Natural variations in fish stocks would make it difficult to prove that any effects were caused by oil. Fish, in general, are able to detect oil even at extremely low concentrations, and may avoid oil spills by swimming away.

32. Frost, K.J., C.A. Mansen, and T.L. Wade. 1994 *Petroleum hydrocarbons is tissues of harbor seals from Prince Williams Sound and the Gulf of Alaska.* Pp. 331-358 In: Marine Mammals and the *Exxon Valdez.* T.R. Loughlin (ed.), 395 pages, Academic Press.

    Summary: It is likely that the primary impact on harbor seals of exposure to crude oil following the EVOS was due to inhalation of volatile, short-change aromatic hydrocarbons. Seals may have been exposed levels of volatile hydrocarbons sufficient to cause respiratory or cardiac arrest or to interfere with normal breathing patterns. Some tissues from seals found dead or collected and oil areas of Prince William Sound in 1989 contained elevated concentrations of petroleum-related hydrocarbons when compared to tissues form seals collected out of the path of the spilled oil. One year after the EVOS, none of the tissues from seals collected in the spilled area showed significantly elevated concentrations. However, average concentrations of hydrocarbons in bile were still significantly higher than those observed for seals from outside the oiled Prince William Sound areas. These data support the hypotheses that harbor seals in Prince William Sound were exposed to high concentrations of petroleum-related hydrocarbons in the spring of 1989. The level of this exposure in Prince William Sound declined in 1990 but was still greater than exposure in the area outside of the spill path. The implication of the results of hydrocarbons analyses for the health of seals is unknown. Levels of hydrocarbons in seal tissues were low. However, since seals metabolize hydrocarbons very efficiently, the levels remaining in tissues when they were sampled underestimate the actual degree of exposure. Essentially, no information is available on the likely effects of hydrocarbons on seals for anything other than short-term experimental exposure. It is important note that chemical analysis did not measure the most volatile and acutely toxic hydrocarbons, which have been documented to cause mortality in other mammals and which are the most likely cause of nerve damage that was observed in oiled seals.

33. St. Aubin, D.J. and J.R. Geraci. 1994. *Summary and Conclusions.* Pp 371-376. In: Marine Mammals and the *Exxon Valdez.* T.R. Loughlin (ed.), 395 pages, Academic Press.

    Summary: How marine mammals behave around an oil spill largely determines how severely they might be affected. During the EVOS, at one time or another, sea otters, harbor seals, porpoises, dolphins, and killer whales were observed swimming in oiled-covered waters. Oiled seals show no tendencies seek out clean beaches and even chose to pup on a contaminated sites two months or more after the spill. Qualitative studies to determine avoidance behavior under the prevailing condition did not command, or perhaps even warrant, high priority. Experience shows that such studies are difficult to interpret in any event, even under fairly controlled circumstances. Despite strong indications that some marine mammals can detect oil, the observations here, as in the past give no assurance that marine mammals will avoid an oil spill. A new understanding of the toxic effects of oil was gleaned form pathologic findings, and also from evaluating animals brought to rehabilitation centers. The consequences of inhaling petroleum vapors were particularly evident during the early phase of the spill, underscoring the harmful character of fresh oil. Sea otters developed pulmonary emphysema and harbor seals exhibited neurologic lesions. Much of the damage to liver, kidney, gastrointestinal, and hematopoietic systems was attributed to starvation and shock secondary to hydrocarbon exposure. Seals exposed to oil in Prince William Sound behaved abnormally. They were lethargic, could be easily approached, and remained hauled out in the face of activities that would normally cause them to enter the water. There have been other accounts of oiled phocid seals behaving the same way. Here for the first time, the clinical affect could be traced due to degenerative lesions in the brain. Data were obtained on the distribution of alphatic and aromatic hydrocarbons in tissues of harbor seals and sea otters. The small number of mammals tested made it difficult to correlate hydrocarbon levels with specific pathologic findings. Nevertheless, the observed patterns did provide clues to the source of hydrocarbons, the route and in some cases the duration of exposure. These findings may serve is a foundation for broader analysis of future events, and may someday help to establish the degree of exposure in situations where other corroborating evidence is equivocal.

33. Harvey, J.T. and M.E. Dahlheim. 1994. *Cetaceans in oil.* In: Marine Mammals and the *Exxon Valdez*. T.R. Loughlin (ed.), 395 pages, Academic Press.

Summary: With limited data, lack of controls, and natural variability, it is difficult to test the effects of oil on cetaceans. If cetaceans cannot detect petroleum products at some distance, a response may not occur until they directly contact oil. Cetaceans may reverse their path, thereby returning to oil-free water. The relatively few observations of cetaceans in or near oil may reflect: (1) the seasonally low density of cetaceans in Prince William Sound: (2) avoidance of the area because of the presence of oil: or (3) avoidance because of increases human activity (i.e., aircraft, vessel, and on land). This is difficult to assess because there were no surveys conducted outside the impacted area. The paucity of observations of cetaceans in oil underscores the difficulty in obtaining quantitative information needed to assess the effects of oil on these animals. Petroleum substances can damage mammalian skin, but experiments with captive cetaceans indicated little affect with exposures of 75 minutes. Petroleum compounds did not significantly reduced epidermal cell proliferation or change lipid composition. The skin apparently was a barrier to hydrocarbons. These results are difficult to interpret, however, because sample sizes were small and results obtained from experience with captive animals may not reflect natural processes. Observations during the EVOS showed that in no case did cetaceans alter their behaviors when in areas with oil. These observations are consistent with other report of cetaceans behaving normally in the presence of oil.

34. Lipscomb, T.P., R.K. Harris, R.B. Moeler, J.M. Pletcher, R.J. Haebler, and B.E. Ballachey. 1993 *Histoathologic lesions in sea otters exposed to crude oil.* Veterinary Pathology 30: 1-11.

Summary: The Exxon Valdez oil spill had a devastating effect on the sea otters in Prince William Sound, and hypothermia was a major problem. Oil contaminated sea otters rapidly become a hypothermic. They devoted themselves to a life-or-death struggle to remove oil by grooming. Feeding is drastically curtailed, and energy stores are rapidly depleted. Grooming is marginally effective at best and results in ingestation of crude oil. By unknown mechanisms, exposure to oil causes interstital pulmonary emphysema which compromises respiration. Their desperate situation causes a powerful stress reaction. Some sea otters succumb to hypothermia rapidly, and no lesions form. Others live long enough to develop interstitial pulmonary emphysema, gastric erosion and hemorrhage, heptic and renal lipidosis, and centrilobular necrosis.

35. Spraker, T.R., L.F. Lowry, and K.J. Frost. 1994. *Gross necropsy and histopatholoogical lesions found in harbor seals.* Pp. 281-311. In: Marine Mammals and the *Exxon Valdez*. T.R. Loughlin (ed.), 395 pages, Academic Press.

Summary: This study documented at the pathological conditions observed in harbor seals collected after the Exxon Valdez oil spill. The study documented several types of lesions that were probably caused by crude oil. Skin irritation, conjunctivitis, and liver lesions occurred more frequently in oiled seals. This damage was relatively mild, and probably reversible, in most cases. Four types of lesions characteristic of hydrocarbon toxicity were found in the brain of oiled seals. These lesions occurred principally in the thalamus probably explained the disorientation and lethargy observed in seals immediately following the spill. It is likely that severely affected seals died prior to sampling, and the animals collected were those that survived the short-term effect of the oil spill.

36. Henk, W.G. and D.L. Mullan, 1996. Common epidermal lesions of the bowhead whale, Balaena Mysticetus. Scanning Microscopy 10 (3): 905-916.

The three common classes of lesions seen here on the skin of the bowhead whale are confined to the superficial epidermis and result in no inflammatory or other dermal response. While it seems clear that the skin lesions described here do not penetrate the epidermis and probably heal without scarring, an exposed stratum coreum offers increased micro-relief on an otherwise smooth surface. Such relief continues to suggest the potential for increased adherence of spilled petroleum.

37. Richardson, W.J. (ed) 1998. *Marine mammals and acoustical monitoring of BPXA's seismic program in the Alaska Beaufort Sea, 1997.* Report from LGL Ltd., King City, Onario, Canada and Greeneridge

Sciences Inc., Santa Barbara, CA for BP Exploration (Alaska) Inc., Anchorage, AK and NNMFS, Anchorage, AK and Silver Spring, MD.

Summary: Marine mammals can be disturbed by underwater sounds from a seismic exploration program. Bowhead whales usually show avoidance reactions to seismic vessels operating within several km. Previous monitoring studies have provided inconclusive results concerning avoidance at greater distances, but subtle behavior reactions may extend to considerably longer ranges. It is not known whether these reactions represent a biologically significant impact. There are few published data on the reactions of either tooth whales or pinnipeds to open water seismic exploration.

Inupiat whalers are especially concerned that seismic programs may displace some bowhead whales farther offshore, making them less accessible to hunters. They also report the whales exposed to seismic noise are more "skittish" and difficult to hunt. Inupiat whalers believe that, during migration, bowhead whales exposed to seismic operations, while migrating west through the Alaska Beaufort Sea can be displaced northward as much as 30 mi. from their normal migration corridor.

In 1996, the onshore/offshore distributions of "seismic" and "non-seismic" samples were not significantly different. In 1997, based on a very small seismic sample, bowheads tended to be seen closer to the shore during periods with seismic. Combined 1996-97 data provided no clear evidence that the general migration corridor was farther from shore at times with, than at times without seismic exploration. These results, reveal no clear effect of the 1996 and 1997 seismic programs on the position of the general migration corridor in the central Alaska Beaufort Sea. However, these analysis were limited by the low number of sightings of bowheads potentially influenced by seismic during 1996-1997, and did not address localized effects.

During the 1996-97 whaling seasons, avoidance of air guns and source vessels by bowheads did not affect subsistence whaling. During the hunting period, the seismic program was restricted to areas west of the hunters base-camps on Cross Island. The Cross Island hunts were successful in both years, with two bowheads landed in 1996 and three in 1997. After the whaling seasons the Nuiqsut whaling captains indicated that they had not perceived any interference by BP's 1996-97 seismic programs west of Cross Island.